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A STUDY OF MOUNTAIN PINE BEETLE INFESTATIONS IN WESTERN WHITE PINE

1936 Investigations

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A STUDY OF MOUNTAIN PINE BEETLE INFESTATIONS IN WESTERN WHITE PINE

DESCRIPTION OF THE STUDY

The infestation study with which this report deals has for its object to study mountain pine beetle infestations in western white pine in order to obtain a better understanding of the factors that govern the behavior of these infestations. The project was begun with an intensive study of the Coeur d'Alene situation, with the expectation that during subsequent years data will be secured from other forests as well. In any event, detailed information from the Coeur d'Alene infestation should result in a better understanding of all mountain pine beetle infestations in white pine and provide a sounder basis for making control recommendations.

The study was begun on June 11, 1936 with a crew of eight CCC enrollees and an experienced foreman, under the direct supervision of Mr. T. T. Terrell and the writer, who alternated on the project. In the organization of the crew it was found most feasible to use one man to locate trees, two for sawyers, four to examine the trees, and one man who spent most of his time in the office computing and totaling the data sheets. After felling the tree the sawyers also secured data on tree heights and diameters and bark thickness at each sample.

During the first part of the project each tree was examined at ten-foot intervals along the bole, starting at five feet. Later, however, the interval was extended to 20 feet, when it was found that this could be done without altering the character of the data. Examinations were made therefore at 5, 20, 40, and 60 feet, etc., up to the height of infestation. The five-foot sample was considered representative of the basal ten feet of the bole; the twenty-foot samples represented the next twenty feet; the forty-foot samples from thirty to fifty feet, etc. The last samples were taken at the midpoint between the top of the last twenty-foot log and the height of infestation. At each point of examination one-half square foot of bark was removed on the north, east, south, and west sides of the tree, and the following data recorded for each sample: number of eggs, larvae, pupae, new adults, new adult emergence holes, parent adult emergence holes, attacks, and inches of egg gallery of the mountain pine beetle; square inches of secondary work; number of Coeloides and other parasites; number of Medetera, Loncheea, Clerids, Ostomids, and Phaonia; number of Cerambycid larvae, square inches of Cerambycid work, and square inches of woodpecker work.

These field records were then given to the office man, who computed the total bark surface of each log and multiplied the number recorded for each of the above headings by half of the bark surface to secure the total for each log. Half the bark surface was used instead

of reducing the various factors to a square-foot basis, because the same result was secured and it was simpler to make but the one division. The totals for each individual factor in each log were then added together and their sum divided by the total bark surface of the tree in order to secure the tree average for each factor. In this way the unequal bark surface represented by the various samples was weighted and the total for the tree was more accurate. In addition, such data as tree class, diameter and bark thickness at each sample, crown shape, rate of growth, presence or absence of wood rot and Armellaria, site, exposure, and total height were recorded for each tree.

Throughout the project, trees which were attacked in 1935 as well as those attacked during the 1936 season were examined. The 1935 trees showed very close to final emergence, while the 1936 trees must yet pass through the winter, so that considerable mortality will undoubtedly occur before emergence. It is the plan of the study, however, to examine trees, first, during the season of attack to secure brood potentials, and second, during the season of emergence to secure final emergence.

GENERAL COMPARISON OF 1935 AND 1936 INFESTATIONS

In considering the Coeur d'Alene infestation during the 1935 and 1936 seasons it is difficult to arrive at a fair comparison, because, as already stated, the 1935 trees were examined just prior to emergence, while the 1936 trees were in a much earlier stage of development, having not yet overwintered. Although a few general comparisons are shown, these comparisons will be much better when the 1937 examinations have been made.

In table I mountain pine beetle brood has been compared for the two seasons.

TABLE I
COMPARISON OF MOUNTAIN PINE BEETLE BROOD
DURING 1935 AND 1936

Year	No. trees	Average brood per square foot					
		Eggs	Larvae	Pupae	New adults	New adult emergence	Total
1935	133	.009	1.1	1.2	3.1	2.3	7.7
1936	78	25.5	40.9	5.7	3.8	1.5	77.4

Table I shows that there are a greater number of eggs and small larvae in the 1936 trees, resulting in a much higher total brood than in the 1935 trees. Although there will be an additional mortality of approximately 50 percent in the 1936 trees, the expectancy is for a more abundant emergence from these trees than from those attacked during 1935. An examination of table I will show that already there are more pupae, new adults, and nearly as many emergence holes in the 1936 trees as are found in the 1935 attacks. Other 1936 trees will be examined during 1937, however, to determine the final emergence.

In table II other general mountain pine beetle attack characteristics are compared for the two seasons.

TABLE II
COMPARISON OF ATTACK CHARACTERISTICS FOR
1935 AND 1936

Year	Square feet of infested bark per tree	Mountain pine beetle			
		Parent adult emergence per sq. ft.	Attacks per sq. ft.	Inches egg gallery per sq. ft.	Inches egg gallery per attack
1935	190	5.7	8.5	100.4	11.8
1936	182	2.1	4.7	55.0	11.8

Table II shows that in general the infestation was similar during the two seasons. The trees attacked were approximately the same diameter and infested to the same height as shown by the average number of square feet of infested bark per tree. The number of attacks and parent adult emergence holes per square foot appear to be greater during 1935 owing to the fact that most of the 1936 trees had not been completely "filled in" and all parent beetles had not yet emerged when the trees were examined. As a result of these fewer attacks the inches of egg gallery per square foot of bark in 1936 are slightly more than half of the number in 1935, although the inches of gallery per attack remain the same.

Considering the possibilities for additional mortality in the 1936 broods, table III has been prepared to show a comparison between bark-destroying agents, parasites and predators during the two seasons.

TABLE III
COMPARISON OF ROBBERS, PARASITES AND PREDATORS
FOR 1935 AND 1936

Year	Number per square foot			Square inches per square foot		
	Parasites	Predators	Cerambycids	Cerambycid work	Secondary work	Woodpecker work
1935	4.7	2.4	0.8	3.2	4.5	6.6
1936	2.0	1.7	0.9	1.5	4.8	0.1

Although not shown in table III, it is known that trees attacked late in the season will undergo additional parasitization during the following season, so that the number of parasites and predators in the 1936 trees will probably be increased, before emergence, to a number comparable to that in the 1935 trees. An increase may also be expected in the amount of Cerambycid and secondary work owing to the fact that these insects will do more feeding before the trees are abandoned. Very little woodpecker work is to be found on the 1936 trees because this usually occurs during the winter months. Approximately 50 percent additional mortality may be expected therefore in the 1936 broods, but it is doubtful if this mortality will reduce the broods as low in numbers as those in the 1935 trees.

In general, the Coeur d'Alene infestation in 1936 was very similar to that in 1935 except that a more abundant emergence is expected in 1937. Whether this will result in a subsequent increase in the number of trees attacked during 1937 or whether the greater emergence will be absorbed by more numerous attacks in larger trees can not be predicted.

THE EFFECT OF VARIOUS PHYSICAL AND PHYSIOLOGICAL FACTORS ON THE MOUNTAIN PINE BEETLE

In discussing those factors which have an influence upon the abundance of the mountain pine beetle it is difficult to isolate any particular one and evaluate its importance without taking cognizance of others which are effective under the same circumstances. For example, a clear-cut correlation of brood abundance according to the site on which the infested tree is growing can not be made without considering the influence of tree diameter, bark thickness, parasites, predators, robbers, etc., on the various sites. Insofar as possible, however, each of the following factors will be considered separately with a minimum of duplication and repetition: period of attack, exposure, site, infestation units, diameter, parasites and predators, bark thickness, intensity of attack, and height of attack on the bole.

Period of Attack

To recall briefly the seasonal history of the mountain pine beetle, attacks occur throughout the developmental season. There are, however, three well-defined peaks during the season, one during June, a second in later July or early August, and the third in September. These represent the three times of the year when the greatest number of attacks occur and have thus been named the early, midseason, and late periods of attack. By far the greatest number of attacks occur during the midseason period, somewhat less in the early period, and relatively few in the late period.

Table IV shows the relative abundance of mountain pine beetle broods in the trees attacked during these three periods.

TABLE IV
ABUNDANCE OF MOUNTAIN PINE BEETLE IN THE THREE ATTACK PERIODS

Year and attack period	1935			1936		
	Early	Midseason	Late	Early	Midseason	Late
Number of trees	44	77	12	34	36	8
Sq.feet bark surface	8179	15667	1461	5220	7653	1346
Eggs per square foot	0	.01	0	12.0	33.6	31.8
Larvae	0. 8	0.9	5.5	39.1	47.1	12.7
Pupae	1.5	0.9	2.5	11.3	2.9	0
New adults	3.2	3.1	2.3	8.2	1.4	0
New adult em. holes	2.0	2.5	2.0	3.1	0.6	0
Total brood	7.5	7.3	12.4	73.8	85.7	44.5

It will be noted in table IV that the maximum brood per square foot occurred during the late attack period in 1935, while in this period in 1936 the minimum brood is present. Obviously, the mature brood per square foot depends partially on the number of eggs laid, which in turn is dependent upon the number of attacks. Other factors which influence the abundance of mature brood are the relative number of parasites, predators and robbers during the various attack periods. In table V these factors are shown in numbers per square foot.

TABLE V

ABUNDANCE OF ATTACKS AND BENEFICIAL AGENTS IN VARIOUS ATTACK PERIODS

Year and period	1935			1936		
	Early	Midseason	Late	Early	Midseason	Late
	Abundance per square foot					
Attacks	6.8	9.4	8.8	4.5	5.0	3.3
Brood	7.5	7.3	12.4	73.8	85.7	44.5
Inches egg gallery	89.3	106.6	96.3	58.8	56.6	30.3
Parasites	7.0	3.7	3.7	4.5	0.7	0.1
Predators	3.8	1.8	1.2	2.1	1.7	0.1
Square inches secondary work	4.9	4.5	6.6	5.5	2.9	13.0
Square inches cerambycid work	5.8	2.2	0.3	1.8	1.0	2.9
Square inches woodpecker work	8.7	6.1	0.1	0.3	0	0

Table V does not help to explain entirely the reasons for the variation in mountain pine beetle broods during the various attack periods. During the 1935 season the early and midseason trees produced approximately the same amount of brood in spite of the fact that the early attacks were subject to considerably more parasitization and work by robbers and predators as well as the fact that there were fewer attacks per square foot in these trees. The only theory that can be advanced to account for this is that the early attacks, being in a more advanced state of development, were more immune from whatever caused the high mortality so noticeable among the larvae in the two later attack periods. The broods in the late-attacked trees are

somewhat more numerous owing to the absence of woodpecker work and the fact that some egg laying by overwintering adults occurs in the spring following the season of attack.

No comparisons can be made with the trees attacked during 1936 owing to the fact that these broods have not developed sufficiently. This is particularly noticeable in the eight trees representing the late-attack period, which contain only eggs and small larvae, indicating that more egg laying will take place.

In general, these data indicate that there is no marked difference in the number of mountain pine beetles produced from the trees in different attack periods, although the more abundant attacks per tree during the midseason attack period would indicate a greater emergence. The main feature of these tables is that in order to make a proper evaluation of any infestation one must have trees in each attack period well represented in order to secure a true average of all factors.

Exposure

To determine the effect of exposure to the sun on the abundance of the mountain pine beetle, the first series of correlations are made on the number of mountain pine beetle per square foot of bark according to the exposure of the terrain on which the trees were growing. Exposures have been grouped into north, east, south, west and creek bottom. In table VI the average brood per square foot of bark has been arranged according to attack period and exposure.

TABLE VI

BROOD PER SQUARE FOOT ACCORDING TO EXPOSURE AND PERIOD OF ATTACK

	1935			1936			Average both seasons
	Early	Midseason	Late	Early	Midseason	Late	
North	2.4	4.5		35.6		98.7	14.1
East	5.7	2.6		21.3	81.3		22.3
South	5.2	3.8		37.5	46.8	30.0	21.0
West	7.1	10.5	10.7				9.4
Creek bottom	10.5	8.8	12.7	83.9	93.9	6.8	47.1

Owing to the poor distribution of trees and the lack of representation on the various exposures, particularly the west exposure during the 1936 season, table VI does little more than indicate that maximum broods are produced in trees growing close to the creek bottoms.

In table VII the 1936 trees have been eliminated owing to the variable stages of development, and all 1935 trees have been grouped regardless of attack period. Parasites, predators and robbers are also shown in addition to brood.

TABLE VII
ABUNDANCE OF VARIOUS FACTORS ACCORDING TO EXPOSURE

Exposure	North	East	South	West	Bottom
Number of trees	22	7	17	39	48
Square feet bark surface	4161	2119	2514	5594	10939
Total brood per sq. ft.	4.0	3.7	4.4	9.4	9.8
Attacks	6.4	7.9	6.5	8.7	9.9
Parasites	2.3	1.3	5.7	4.2	6.3
Predators	2.1	1.8	1.2	1.2	3.4
Sq. in. secondary work	3.9	5.5	11.0	3.5	3.9
Sq. in. Cerambycid work	2.4	3.0	2.0	2.8	4.0
Sq. in. woodpecker work	4.6	5.5	9.5	5.0	7.6

The outstanding feature of table VII is the apparent optimum conditions presented by the trees growing under moist conditions. Both attacks and brood per square foot are more abundant on west and creek-bottom exposures, while parasites, predators and Cerambycid work also reach their maximum in trees growing in creek bottoms. It is quite obvious, however, that secondary bark beetles, which are much more tolerant of heat, appear to prefer the warmer, drier southern and eastern exposures. Woodpecker work is more abundant on southern exposures in all probability as a result of the sunlight on this exposure during the winter months when most of the woodpecker activity occurs. In general then, the cardinal direction of exposure has little to do

with the number of mountain pine beetles which reach maturity. There is, however, an apparent correlation between brood and the moisture of the site. Why trees growing under optimum conditions should be preferable to the mountain pine beetle and produce maximum broods is difficult to answer. It is possible that trees on moist sites, after having once been attacked, succumb to the attack more readily than trees which have been forced to compete with adverse growing conditions.

Additional correlations on exposure were made by dividing the infested bark surface of each tree into quadrants according to the direction of exposure and averaging the data for each quarter. Table VIII shows the averages for all attack periods during the two seasons.

TABLE VIII
MOUNTAIN PINE BEETLE ABUNDANCE
ACCORDING TO EXPOSURE OF THE SIDE OF THE TREE

	1935				1936			
	North	East	South	West	North	East	South	West
Number of trees	129	129	129	129	76	76	76	76
Bark surface	6128	6128	6128	6128	3463	3463	3463	3463
Attacks	8.3	8.4	8.6	8.3	4.6	4.3	3.7	3.8
Eggs	0.0	.01	.02	0.0	26.1	21.7	23.9	17.8
Larvae	1.5	1.3	1.0	1.0	44.6	48.7	37.3	37.1
Pupae	1.3	1.3	1.2	0.9	6.8	6.3	4.5	4.9
New adults	3.4	3.1	3.0	3.0	4.7	4.0	3.8	2.6
New adult em. holes	2.2	2.5	2.4	2.3	1.2	0.9	0.5	0.9
Total brood	8.4	8.3	7.5	7.2	83.5	81.6	70.1	63.4

Table VIII shows that the maximum brood is found on the north and east sides of the tree, while the minimum brood, contrary to expectation, is found on the west side. This is an apparent contradiction to a previous statement in which it was postulated that maximum broods were found in trees growing on west and creek-bottom exposures. However, it is to be noted that those trees on the western exposures were in all probability growing close to the creek bottom and thus fall in the wet-site class. Thus, it is apparent that the cooler sides of trees growing on wet sites represent optimum developmental conditions. Table IX has been prepared to show similar data concerning parasites, predators and robbers.

TABLE IX
PARASITES, PREDATORS AND ROBBERS ON FOUR EXPOSURES OF THE TREE BOLE

	1935				1936			
	North	East	South	West	North	East	South	West
Parasites	4.8	5.2	4.8	4.1	2.0	1.6	1.3	1.9
Predators	1.9	2.1	2.7	2.3	1.8	1.4	1.8	1.6
Square inches secondary work	4.7	5.5	4.8	4.1	3.0	3.2	5.7	5.5
Square inches Cerambycid work	2.7	3.2	4.2	3.0	1.0	1.5	1.7	1.3
Square inches woodpecker work	5.6	7.2	6.3	4.5	.004	.002	0.0	0.0

Table IX shows quite clearly that there is not sufficient variation in these agencies detrimental to the mountain pine beetle to account for the differences in brood found on the different sides

of the tree. In general then, attacks and mountain pine beetle broods are more abundant on the north and east sides of the tree, while those agencies which destroy the mountain pine beetle tend to be approximately equal regardless of exposure.

Although this holds true for the general average of the infestation during the 1935 and 1936 seasons, there is a slight variation in the different attack periods, probably as a result of the different temperatures which prevail during the early and late portions of the season. The following six tables show similar data representing the different attack periods.

TABLE X

MOUNTAIN PINE BEETLE ACCORDING TO EXPOSURE OF THE BOLE IN EARLY ATTACKS

	1935				1936			
	North	East	South	West	North	East	South	West
Number of trees	44	44	44	44	32	32	32	32
Bark surface	2045	2045	2045	2045	1214	1214	1214	1214
Attacks	6.7	6.5	7.3	7.0	5.3	4.8	4.0	4.5
Eggs	0.0	0.0	0.0	0.0	19.2	15.4	6.0	11.0
Larvae	1.0	0.5	0.6	1.2	41.5	38.4	32.4	33.9
Pupae	1.7	1.3	1.5	1.6	15.0	9.9	10.5	10.1
New adults	3.8	2.9	3.3	2.8	11.2	9.0	7.4	6.6
New adult emergence holes	1.7	2.2	2.2	1.9	3.1	1.1	0.8	1.0
Total brood	8.2	6.8	7.5	7.5	90.0	73.9	57.1	62.6

TABLE XI

ABUNDANCE OF BENEFICIAL AGENTS
ACCORDING TO EXPOSURE OF THE BOLE IN EARLY ATTACKS

	1935				1936			
	North	East	South	West	North	East	South	West
Parasites	6.7	6.9	7.9	6.0	4.3	4.2	2.9	4.1
Predators	3.0	3.7	4.7	3.5	2.4	1.8	2.1	1.6
Square inches secondary work	3.8	4.4	6.3	4.8	2.0	1.4	7.4	6.5
Square inches Cerambycid work	4.4	6.1	7.0	5.5	1.1	1.7	1.7	1.4
Square inches woodpecker work	6.9	12.4	8.7	6.0	.01	.08	0	0

TABLE XII

MOUNTAIN PINE BEETLE ACCORDING
TO EXPOSURE OF THE BOLE IN MIDSEASON ATTACKS

	1935				1936			
	North	East	South	West	North	East	South	West
Number trees	73	73	73	73	35	35	35	35
Bark surface	3713	3713	3713	3713	1813	1813	1813	1813
Attacks	9.2	9.4	9.3	9.1	4.6	4.5	3.7	3.8
Eggs	0.0	.02	.04	0.0	30.4	26.9	34.4	21.3
Larvae	1.3	1.3	0.6	0.6	55.8	64.5	45.8	47.4
Pupae	1.0	1.1	0.8	0.6	2.9	5.4	1.5	2.6
New adults	3.3	3.2	2.8	3.2	1.5	1.6	2.3	0.6
New adult em. holes	2.5	2.7	2.5	2.6	0.2	1.0	0.5	1.1
Total brood	8.1	8.3	6.8	7.0	90.7	99.4	84.5	72.9

TABLE XIII
ABUNDANCE OF BENEFICIAL AGENTS
ACCORDING TO EXPOSURE OF THE BOLE IN MIDSEASON ATTACKS

	1935				1936			
	North	East	South	West	North	East	South	West
Parasites	3.8	4.4	3.2	3.3	1.0	0.2	0.6	0.8
Predators	1.3	1.3	1.7	1.8	1.9	1.5	2.0	1.9
Square inches secondary work	5.1	5.7	3.8	3.7	2.7	1.8	4.6	3.0
Square inches Cerambycid work	1.9	1.9	3.1	1.9	1.0	1.0	1.0	1.2
Square inches woodpecker work	5.4	5.1	5.5	4.1	0.0	0.0	0.0	0.0

TABLE XIV
MOUNTAIN PINE BEETLE ACCORDING
TO EXPOSURE OF THE BOLE IN LATE ATTACKS

	1935				1936			
	North	East	South	West	North	East	South	West
Number trees	12	12	12	12	8	8	8	8
Bark surface	370	370	370	370	336	336	336	336
Attacks	7.4	9.0	8.6	7.9	3.2	3.2	4.3	2.8
Eggs	0.0	0.0	0.0	0.0	36.2	22.9	39.4	28.9
Larvae	6.9	5.6	6.1	4.3	9.5	14.6	21.0	4.7
Pupae	3.1	2.8	2.8	1.3	0.0	0.0	0.0	0.0
New adults	1.5	4.1	3.0	1.0	0.0	0.0	0.0	0.0
New adult em. holes	1.8	3.2	2.0	1.1	0.0	0.0	0.0	0.0
Total brood	13.3	15.6	13.9	7.8	45.6	37.5	60.5	33.6

TABLE XV

ABUNDANCE OF BENEFICIAL AGENTS
ACCORDING TO EXPOSURE OF THE BOLE IN LATE ATTACKS

	1935				1936			
	North	East	South	West	North	East	South	West
Parasites	3.7	3.4	4.7	2.5	0.1	0.1	0.1	0.1
Predators	1.1	1.1	2.0	0.5	0.1	0.1	0.2	0.1
Square inches secondary work	5.5	9.0	7.0	5.0	8.6	18.2	7.9	17.4
Square inches Cerambycid work	0.3	0.3	0.4	0.2	1.0	3.4	5.5	1.9
Square inches woodpecker work	0.2	0.1	0.0	0.2	0.0	0.0	0.0	0.0

In the preceding six tables the variation in abundance of mountain pine beetle and beneficial agents has been shown for the different sides of the tree during the three attack periods. By comparing these tables with tables VIII and IX, it will be seen that the main difference lies in the fact that parasites are more abundant on the warmer sides of the trees during the early and late attack periods when air temperatures are lower. Mountain pine beetle brood also tends to be more evenly distributed in the trees attacked during these two periods and, in fact, is considerably higher on the south side of trees attacked late in 1936.

In general, it may be said that mountain pine beetle parasites and predators are most abundant on the north and east sides of trees. On the other hand, robbers prefer the warmer exposures. In the early

and late attack periods, however, when lower temperatures prevail, the tendency is for parasites and predators to be on the warmer exposures and for the mountain pine beetle to be more evenly distributed.

Site

It was shown in table VII that mountain pine beetle broods were apparently more abundant on the west and creek-bottom exposures, that is, on the more moist sites. In consequence of this indication, table XVI has been prepared to show the relation between broods on wet, medium, and dry sites.

TABLE XVI
BROOD CONDITION ON VARIOUS SITES FOR 1935 AND 1936

	1935			1936		
	Wet	Medium	Dry	Wet	Medium	Dry
Number of trees	35	40	59	11	46	21
Bark surface	7192	8211	9798	3185	7641	3393
	number per square foot					
Attacks	8.6	10.0	7.8	4.5	4.6	3.8
Total brood	12.1	8.9	3.5	138.6	76.6	47.6
Parasites	8.2	3.7	3.2	1.8	2.3	1.6
Predators	3.9	2.5	1.3	2.2	1.6	1.5
Square inches robber work	21.5	10.0	13.6	4.2	5.3	10.6

In table XVI it is quite apparent that there is a decided correlation between site moisture and the abundance of insect life beneath

the bark. In spite of the relatively equal attacks on the sites, and the greater numbers of parasites, predators and robber work in those trees growing on wet sites, these trees produce the maximum brood. This point is more clearly shown in table XVII, which is an average of the same data for the two seasons.

TABLE XVII
BROOD CONDITION ACCORDING TO SITE MOISTURE

Average for 1935 and 1936 Seasons

Site moisture	Number trees sampled	Total sq.ft. bark surface	Average infested bark per tree	Average number per square foot: Brood	Attacks	Parasites	Predators	Average total brood per tree
Wet	46	10377	225	50.9	7.4	6.2	3.4	11452
Medium	86	15852	184	41.5	7.3	3.0	2.0	7636
Dry	80	13191	164	14.8	6.8	2.7	1.3	2427

It is at once apparent from the preceding table that, although the number of attacks per square foot is approximately equal on all three sites, there is a greater brood survival on wet sites and a greater amount of infested bark surface per tree, thus making a much greater total brood per tree than on dry sites. This is comparable with conditions known since 1925 to exist with regard to brood survival of the Black Hills beetle. In addition, although beneficial insects are more numerous on wet sites, they represent a greater proportion of the population on the dry sites. This fact is of practical application not only in determining which areas need control but also on those control projects which have been delayed by snow and inclement weather.

When it is seen that the projected plan of control can not be completed, the control administration can direct the work during the remaining time into areas where control will be of greatest benefit.

Areas

During the course of maintenance control work on the Coeur d'-Alene Forest, when it was necessary to select those areas deemed needful of control, it was realized that a sounder basis than the number of infested trees per acre was needed in making this selection. Hence, one of the primary objects of the Coeur d'Alene infestation study is to establish a biological index whereby the potentiality of an infestation can be determined. Although such an index can not be established by one season's work, the following data are included to show that considerable differences do exist between the various units on the Coeur d'Alene Forest.

Table XVIII shows the condition of the infestation on seven units just prior to emergence in 1936.

TABLE XVIII
INFESTATION ACCORDING TO UNITES

1935 Trees

	Name of unit						
	Cascade	Honeysuckle	Clay	North Yellow Dog	Yellow Dog River	Sissons	Potter
Number of trees	13	55	10	13	12	2	28
Total infested bark surface	2509	13004	2020	2569	2340	226	3099
	number per square foot						
Attacks	5.8	9.1	9.7	8.8	4.7	8.3	8.5
Brood	4.2	6.9	6.6	10.2	8.6	0.6	11.0
Parasites	3.9	2.6	9.1	6.5	4.6	0.5	5.6
Predators	1.4	2.7	8.4	1.6	2.4	0.3	0.8
Robbers	21.6	13.6	15.8	18.8	14.5	6.3	9.2

It is apparent in table XVIII that there was a decided difference in the amount of brood emerging per square foot in these different areas. Earlier work has shown that emerging brood comprises equal numbers of male and female beetles and that each attack represents one female beetle. Thus one can compare half of the total emerging brood with the number of attacks to determine the percentage of increase or decrease which has occurred during any one season. It is obvious therefore that on this basis all areas should show a decrease in the number of trees attacked during 1936. Table XIX shows the actual percentage of decrease in the units ascertained from a survey of the forest, as well as the anticipated decrease based on brood and attacks. In calculating the anticipated decrease the following formula was utilized:

$$\text{Percent decrease} = 100 - \frac{(1/2 \text{ brood per square foot})}{(\text{No. attacks per square foot})}$$

and the percentage was determined on the basis of both the 1935 and 1936 attacks.

TABLE XIX
COMPARISON OF ACTUAL AND ANTICIPATED DECREASE ACCORDING TO UNITS

	Name of unit						
	Cascade	Honey-suckle	Clay	North Yellow Dog	Yellow Dog River	Sissons	Potter
	percent	percent	percent	percent	percent	percent	percent
Actual decrease	50	34	78	96	53	68	70
Anticipated decrease on basis of 1935 attacks	63	62	72	43	9	66	36
Anticipated decrease on basis of 1936 attacks	47	30	73	13	0	30	0

It is at once apparent in table XIX that although some of the percentages are sufficiently close, others are decidedly at variance. This does not necessarily imply that the decreases calculated from the infestation study are wrong in every case, because a percentage survey such as the annual survey of the Coeur d'Alene Forest may not be entirely accurate for small subdivisions of the forest even though it is accurate for the forest as a whole.

Any formula to determine the potentiality of an infestation must not include an unpredictable factor such as the density of the attacks which are to occur during the following season. Considering the anticipated decrease on the basis of 1935 attacks, Cascade, Sissons, and Clay are approximately correct. In Potter Creek the actual reduction was higher than anticipated because one-fourth of the infested

trees were treated by tree injection during the 1935 season. Honeysuckle, North Yellow Dog, and Yellow Dog River are all decidedly at variance. In explanation of these differences, several factors may be of importance. In the first place, the number of trees sampled may not have been sufficient to give a true average. Secondly, the type of material and the intensity with which it is attacked have considerable influence on the number of infested trees. For example, it will be shown later that attacks in windfalls are much less numerous than in standing trees. In the Honeysuckle unit there were 170 windfalls attacked in 1935 and 229 in 1936. Since windfalls are attacked much more lightly than standing trees, this means that more trees can be attacked by the same number of beetles with the result that the decrease in infested trees is less than anticipated even though there has been a decided reduction in broods. Size of the tree and length infested may also materially alter the increase or decrease. Thus to consider the extremes, if the beetles emerge from large, heavily attacked, standing trees with a long infested length, and attack small, unhealthy, weakened trees or windfalls, there will be an apparently rapid increase in the infestation even though the actual number of insects remains the same. Conversely, if the infestation emerges from the lightly attacked material mentioned above, and goes into large trees, there will be an apparently decided reduction in the infestation.

In determining the potentiality of any given infestation therefore one must keep separate the actual increase or decrease in infested trees and the anticipated fluctuation indicated by brood examinations. It is apparent that the true index is indicated by the number of female beetles produced per attack, and in order to make the index workable during any season of the year a constant must be applied for expected mortality and another for parent adult emergence. The mortality constant must be determined on the basis of beneficial insects and corrected for each stage in the insect's development. Additional study is to be given this point during succeeding seasons.

Tree Diameter

In this section the effect of tree diameter on both the mountain pine beetle and beneficial insects will be discussed. It is expected that the more infested bark surface on the tree the greater will be the total brood produced; table XX, however, has been prepared on a square-foot basis to show the effect of the size of the tree on various agencies.

TABLE XX
EFFECT OF TREE DIAMETER ON MOUNTAIN PINE BEETLE
AND BENEFICIAL INSECTS

Tree diameter	Trees sampled	Bark surface	Average per square foot: Brood	Attacks	Egg gallery	Parasites	Predators	Robber
inches	no.	sq.ft.	no.	no.	inches	no.	no.	sq.in.
6-10	20	1096	3.0	6.8	67.9	5.4	0.7	21.2
11-12	20	2316	6.1	6.7	79.1	11.9	1.1	11.2
13-18	52	9678	7.8	7.9	98.5	4.5	1.5	11.6
19-24	32	8685	8.3	9.4	108.7	4.2	2.7	17.3
25+	9	3542	8.5	9.4	114.4	2.0	5.6	15.84

Table XX shows that the trees below 10 inches d.b.h. attacked during 1935 produced a negligible number of mountain pine beetles, while trees above 10 inches produced mountain pine beetles proportionate to the number of attacks. It is interesting to note that, in spite of the nearly equal attacks, there is a decided increase in the amount of egg gallery from the smallest to the largest trees. Parasites were most abundant in the small trees, while predators appear to prefer the large trees. These variations, although apparently dependent upon tree diameter, are in reality affected by bark thickness, which in turn is influenced somewhat, but not entirely, by tree diameter. The factor of bark thickness will be discussed following the next section on the effect of beneficial insects.

It is apparent from the preceding discussion that at the present stage of the infestation it is not necessary to treat trees under 10

inches in diameter. In fact, damage will result through the destruction of beneficial insects when these trees are treated.

Beneficial Insects

One of the most important agencies influencing the abundance of the mountain pine beetle is that group of insects including the parasites, predators, and robbers. Table XXI has been arranged to show the abundance of predators, robbers and D. monticolae brood according to the number of parasites per square foot of bark.

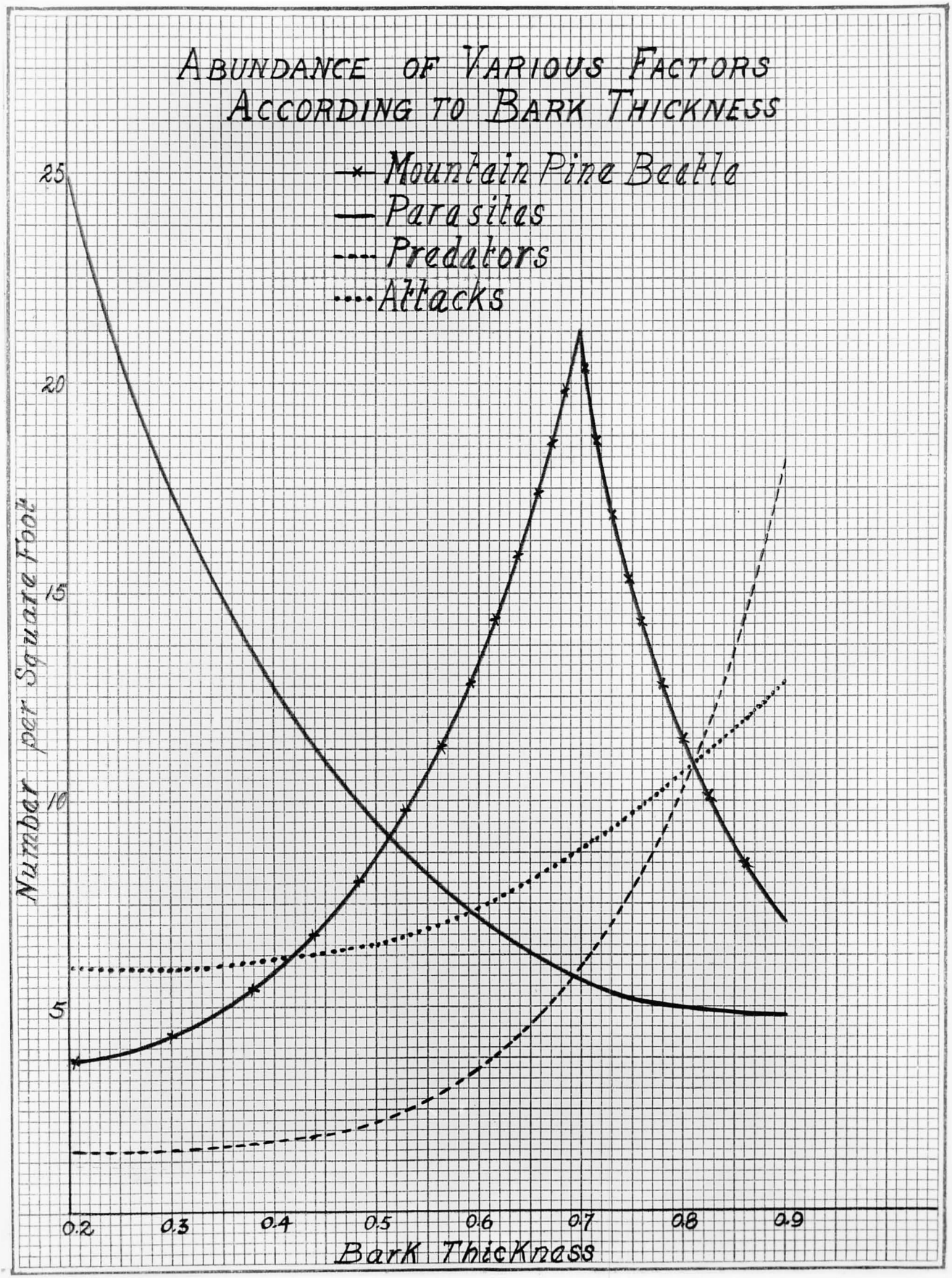
TABLE XXI
THE EFFECT OF PARASITES ON THE
ABUNDANCE OF MOUNTAIN PINE BEETLES

Parasites per square foot	Trees sampled	Bark surface	Average per square foot of bark: Brood	Attacks	Predators	Robber work	Woodpecker work
no.	no.	sq.ft.	no.	no.	no.	sq.in.	
1-5	88	18364	7.7	8.8	2.2	6.2	5.5
6-10	26	4154	9.4	8.7	3.1	10.4	7.4
11-15	9	1544	7.1	7.3	2.2	13.1	17.8
16-20	2	275	3.6	7.7	3.9	4.9	0.9
21-25	5	567	8.8	5.5	4.8	18.5	12.0
26+	3	413	4.3	3.8	2.8	31.6	0.8

Although parasites undoubtedly do have considerable value in reducing the number of mountain pine beetles, this fact is not demonstrated very clearly in table XXI. When the ratio of brood to attacks is considered, there is very little difference in brood per square foot with the different concentrations of parasites. This may result from the fact that there are too few trees representing the higher concentrations of parasites, or it may indicate that parasites

concentrate on the more abundant broods, thus reducing them to a common level.

When parasites, predators, and mountain pine beetle brood are plotted on bark thickness as shown in figure 1, it at once becomes apparent that maximum mountain pine beetle brood is produced at that point where there is the least number of beneficial insects. Progressing from this point toward the thinner bark, the abundance of predators decreases, but there is a rapid increase in the number of parasites. In the direction of the thicker bark, parasites decrease in abundance, but predators increase. Whether this results from the influence of the predatory or parasitic agents or whether it indicates an optimum bark thickness for mountain pine beetle development is a question which presents itself after examination of figure 1. It is evident, however, that more attacks are made in the thick-barked portions of the tree, indicating that thick bark appears to be preferable to the insect.


Abundance of Various Factors According to Bark Thickness
Mountain Pine Beetle
Parasites
Predators
Attacks
25
20
15
10
5
Number per Square Foot
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Bark Thickness

Bark Thickness

It has already been pointed out that bark thickness has a considerable influence not only upon the mountain pine beetle but also upon the parasitic and predacious enemies of this insect. It has been shown that the diameter had an indirect influence resulting from bark thickness, and in figure 1 it was apparent that parasites prefer thin bark, while predators prefer thick bark. Table XXII has been arranged to show the influence of bark thickness on each individual parasite and predator.

TABLE XXII
THE EFFECT OF BARK THICKNESS ON THE
MOUNTAIN PINE BEETLE AND ITS ENEMIES

Bark thickness in inches	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Number samples	30	40	81	74	52	10	10	8
Bark surface	856	938	2612	2044	2184	404	420	426
Coeloides	24.0	14.3	8.6	10.5	5.7	3.4	3.9	2.1
Other Hymenoptera	0.9	0.5	0.1	0.3	0.5	0	0.3	3.4
Total Parasites	24.9	14.8	8.7	10.8	6.2	3.4	4.2	5.5
Medetera	0.6	0.3	0.4	0.8	2.3	3.3	1.4	7.7
Lonchaea	1.6	0.5	0.4	1.1	3.7	3.0	3.9	7.9
Clerids	0.2	0.4	0.6	0.7	0.6	0.4	0.2	2.2
Ostomids	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.2
Phaonia				0.02				
Total predators	2.5	1.3	1.6	2.82	6.8	6.9	5.6	18.0
D.m. brood	5.5	2.5	4.9	7.5	13.3	21.4	5.0	10.7
Attacks	6.7	6.2	5.8	6.9	9.5	10.8	7.7	12.7
Parent emergence	5.3	3.9	5.6	7.1	9.7	7.0	8.5	12.0

Considering the parasites first, it is at once apparent in table XXII that Coeloides is most abundant in the thinner bark, while more than half of the other Hymenopterous parasites are found in the thickest bark. This results from the habits of the two different groups of parasites. The female Coeloides dendroctoni Cush. oviposits through the bark and is thus limited in oviposition to bark which is not thicker than the length of her ovipositor. Cecidostiba dendroctoni Ash. and Pachyceras ecoptogastri Ratz., on the other hand, make use of parent adult emergence holes to go beneath the bark and oviposit directly on the larvae. An examination of table XXII will show that these small Chalcids, as well as all predators, are more numerous in the thicker bark.

It was thought that trees growing under different moisture conditions might have decided differences in bark thickness and thus explain why mountain pine beetle broods were more abundant on wet sites. Table XXIII shows the average bark thicknesses at the base of the tree for the three sites, and table XXIV gives a comparison of bark thickness at a height of 15 feet.

TABLE XXIII
AVERAGE BARK THICKNESS AT FIVE FEET
ON DIFFERENT SITES

Diameter	Dry			Medium			Wet		
	Trees	Range	Aver.	Trees	Range	Aver.	Trees	Range	Aver.
in.	no.	in.	in.	no.	in.	in.	no.	in.	in.
6-11	20	.15- .6	.33	8	.15-.35	.26	11	.2-.6	.26
12-17	36	.2-1.0	.44	39	.25-.8	.37	14	.25-.8	.54
18-23	16	.25- .8	.51	23	.35-1.0	.49	16	.35-1.0	.57
24+	4	.35-.75	.56	4	.35-1.2	.78	5	.4 -1.1	.69

TABLE XXIV
AVERAGE BARK THICKNESS AT FIFTEEN
FEET ON DIFFERENT SITES

Diameter	Dry			Medium			Wet		
	Trees	Range	Aver.	Trees	Range	Aver.	Trees	Range	Aver.
in.	no.	in.	in.	no.	in.	in.	no.	in.	in.
6-11	20	.15-.6	.26	8	.15-.25	.20	11	.15-.4	.21
12-17	36	.15-.7	.33	39	.2-.6	.28	14	.2-.6	.40
18-23	16	.2-.8	.43	23	.25-.6	.36	16	.2-.8	.45
24+	4	.3-.65	.48	4	.3-.8	.56	5	.25-1.1	.54

These two tables indicate that on dry sites the bark of the smaller-diameter trees is thicker than on the more moist sites. However, the reverse is true of the larger trees. The wide range of bark thickness which occurs within each diameter class is also to be noted in these tables. This wide range is shown more clearly in table XXV, in which the trees are recorded in one-inch diameter classes.

TABLE XXV
RANGE IN BARK THICKNESS
FOR DIFFERENT DIAMETER CLASSES

Site	Diameter in inches																			
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Dry	.2	.2	.3	.15	.2	.4	.2	.2	.3	.25	.35	.35	.25	.3	.45	.3	.6	.4	.35
	.2	.2	.4	.4	.5	.6	.3	.8	.7	.8	1.0	.45	.7	.8	.8	.4	.8	.5	.8
Medium			.15	.25	.2	.25	.25	.2	.25	.25	.3	.25	.35	.35	.4	.35	.25	.6	.35
			.2	.3	.25	.35	.35	.6	.8	.5	.8	.7	1.0	.8	.5	.45	.4	1.0	1.2
Wet	.2	.2	.3	.2	.2	.25	.4	.5	.3	.4	.3	.4	.5	.35	.45	.35	.45	.4	
	.2	.2	.3	.3	.6	.7	.6	.6	.8	.8	.4	.8	.8	.6	1.0	.45	.6	1.1	

Table XXV shows that bark thickness is not constant even within each diameter class. Hence it is not surprising, since the bark is thicker on smaller trees and thinner on larger trees on dry sites than on moist sites, that the average bark thickness is approximately the same on all three sites as shown in table XXVI.

TABLE XXVI
AVERAGE BARK THICKNESS AND DIAMETER
ON THREE SITES

Site	Trees	Average d.b.h.	Bark thickness at five feet	Bark thickness at fifteen feet
	no.	in.	in.	in.
Dry	76	15.7	.43	.34
Medium	74	16.7	.42	.32
Wet	46	17.1	.50	.39

It can be said then that bark thickness is an important factor both directly and indirectly in determining not only the presence but the abundance of mountain pine beetle broods. Directly, because the beetle apparently prefers thick bark and can not develop in bark

thinner than .2 inch, and indirectly because bark thickness influences the abundance of beneficial insects.

Density of Attack

The factor of density of attack is one that has been discussed by a number of authors. A recent article by G. R. Gobeil[1/] concerning Ips perturbatus mentions that the high percentage mortality is the most striking character of all the data, and that it is almost entirely due to the factor density of attack. J. J. De Gryse[2/] mentions a method of analyzing bark-beetle population proposed by Golovjanko, which was later modified by Iljinsky. This method postulated that a decrease in the density of attack is followed by (1) an increase in the number of larval tunnels, and (2) an increase in the percentage of larvae successfully completing their development.

Within limits these facts are substantiated by this infestation study. There are, however, other factors which have an important bearing on the abundance of brood, as shown in previous tables. Table XXVII shows the abundance of mountain pine beetles, parasites, predators, and egg gallery according to the number of attacks per square foot.

1/ Gobeil, A. R. 1935. Population study of Ips perturbatus Eichh. Sixth annual report of the Entomological Society of Ontario.

2/ De Gryse, J. J. 1934. Quantitative methods in the study of forest insects. Scientific Agriculture 19:9:477-495.

TABLE XXVII
POPULATION OF D. MONTICOLAE AND ITS ENEMIES
ACCORDING TO DENSITY OF ATTACK

	Number of attacks per square foot								
	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15&18	28&36
Number of trees	11	20	26	24	25	13	8	4	2
Square feet of bark	1664	3573	4600	4702	4579	3615	1558	717	309
D.m. per square foot	5.0	6.9	4.5	6.3	12.1	6.5	16.3	9.0	4.7
Total egg gallery	42.3	67.4	79.6	101.7	117.8	131.8	141.4	170.2	149.4
Egg gallery per attack	24.2	19.2	14.4	13.5	12.3	11.4	10.4	10.3	4.7
Parasites	6.9	6.5	4.6	4.5	5.5	2.8	3.3	2.7	1.7
Predators	2.4	1.9	2.5	1.7	2.7	3.5	3.4	0.4	0.3

Table XXVII shows that maximum mountain pine beetle broods are produced when there are from 9 to 14 attacks per square foot. More or less attacks are associated with a reduction in the number of beetles maturing. If the attacks were above their optimum number, therefore, a reduction in their numbers would result in an increase in the abundance of brood, as stated by Golovjanko. If, however, the attacks were at their optimum number, any further reduction would also result in a decrease in D. monticolae brood, and the theory would not hold true.

There are three major factors which enter into a consideration of this subject: (1) potential brood according to the number of eggs

laid, (2) abundance of enemies, and (3) the amount of food destroyed by egg gallery construction and other agencies. Considering the first of these, neither the number of attacks nor the total length of egg gallery are satisfactory criteria of the number of eggs laid. It will be seen in table XXVII that where there are fewer attacks there is a smaller amount of egg gallery but a decidedly greater length of egg gallery per attack. This holds true until the point is reached at which the attacks are so numerous that both the total length and length per attack must necessarily suffer a substantial reduction. In addition, it will be shown later that practically all eggs are laid before the eleventh inch of egg gallery has been reached, so that any gallery over eleven inches in length does not produce any more brood than a gallery exactly that length. Thus it is apparent that the greatest efficiency in gallery construction is secured when there are from 9 to 15 attacks per square foot.

Enemies of the mountain pine beetle present a somewhat more complex situation. It will be noted in table XXVII that parasites are more abundant in lighter attacks, while predators are more numerous in heavy attacks except where attacks are too numerous. This situation results, however, not from the density of the attack but because parasites are limited to thinner bark which is attacked by fewer beetles, while predators are usually found most abundant where maximum brood is produced. The correlation of maximum predators with

maximum brood in all probability results from the fact that more predators survive where food is more plentiful. It is believed that oviposition by predators is approximately equal in all bark thicknesses, but that more mortality occurs where mountain pine beetle broods are less abundant due to starvation and cannibalism. It is apparent therefore that the slight variation in abundance of beneficial insects shown in table XXVII is not sufficient to cause the difference in amount of brood, particularly because predators are more abundant where maximum brood is found.

The amount of bark destroyed in egg gallery construction is undoubtedly the reason upon which the density of attack hypothesis is based. Obviously the more bark that is destroyed the less food there will be for the developing larvae. However, in a consideration of this subject cognizance must be taken not only of gallery construction but all other bark-destroying agencies as well. In table XXVIII is shown the amount of bark destroyed by Cerambycids, secondaries, woodpeckers, and in egg-gallery construction.

TABLE XXVIII
AMOUNT OF BARK DESTROYED BY VARIOUS AGENTS
ACCORDING TO DENSITY OF ATTACK

Destroying agent	Number of attacks per square foot			
	1-5	6-10	11-15	16+
	sq. in.	sq. in.	sq. in.	sq. in.
Egg gallery construction	13.4	20.2	26.2	32.4
Cerambycid work	5.0	4.3	0.9	1.4
Secondary work	7.4	4.1	0.8	3.8
Woodpecker work	6.1	7.7	2.2	0.3
Total	31.9	36.3	30.1	37.9

In preparing table XXVIII gallery construction was computed on an average width of 0.2 inch. This is somewhat wider than a normal gallery, but this average width was selected to care for the wide portions of the gallery ends, where feeding is done, and the short lateral branches resulting from feeding of the male beetle. Woodpecker work has been included because, where this work occurs, the bark has been completely removed so that egg gallery and woodpecker work were all that was counted where work of this nature had been done.

Table XXVIII shows that, although more space is utilized for gallery construction where the attacks are denser, other factors enter to make the total amount of bark destroyed approximately equal regardless of the number of attacks. It is natural that where the space is not utilized to its capacity, secondaries and Cerambycids enter to make use of it. Thus it is seen that the total amount of bark destroyed in each attack grouping is approximately equal.

These facts point to but one conclusion, namely, that the potential brood indicated by the number of eggs is the criterion which determines the abundance of brood. Where the attacks are of such numbers as to produce the maximum number of eggs with a minimum amount of egg gallery construction, the maximum number of individuals will reach maturity.

Height Along the Bole

In a study such as the infestation study, more trees could be sampled and considerable time saved if it were possible to ascertain the

point along the bole at which the average brood for each tree occurred. In this way the average for each tree could be secured by four samples taken at one height. In the following four tables the averages for various factors at different heights are compared with the averages for the same factors for the tree. Because of the fact that maximum and average abundance for each agent will depend upon the size of the tree, the trees have been divided into four diameter classes, and each table represents a separate class. Table XXIX is for trees from 6-12 inches d.b.h., table XXX for trees 13-18 inches, table XXXI for trees 19-24, and table XXXII for trees over 25 inches d.b.h.

TABLE XXIX
COMPARISON OF AVERAGES AT VARIOUS HEIGHTS
WITH AVERAGE FOR ALL TREES IN GROUP

Trees 6-12 inches d.b.h.

Height	Trees sampled	Bark surface	Average per square foot: Brood	Attacks	Parasites	Predators	Robber work
ft.	no.	sq.ft.	no.	no.	no.	no.	sq.in.
5	35	915	7.7	8.5	11.7	1.9	15.2
15	28	740	3.7	6.9	11.3	0.5	8.0
25	16	448	2.5	6.7	12.5	0.4	12.9
35	15	353	1.8	4.6	8.0	0.5	8.3
45	9	226	4.2	4.8	18.6	0.5	10.3
55	3	57	0	1.0	4.1	0.5	21.7
65	2	34	1.1	2.6	3.4	0	15.8
Average for all trees	35	2773	5.1	6.8	9.8	1.0	14.3

TABLE XXX

COMPARISON OF AVERAGES OF VARIOUS HEIGHTS WITH AVERAGE FOR ALL TREES IN GROUP

Trees 13-15 inches d.b.h.

Height	Trees sampled	Bark surface	Average per square foot: Brood	Attacks	Parasites	Predators	Robber work
ft.	no.	sq.ft.	no.	no.	no.	no.	sq.in.
5	52	2060	13.9	9.9	3.9	2.5	6.5
15	38	1647	6.1	8.2	4.6	1.0	9.4
25	37	1868	7.5	8.3	4.3	1.5	12.5
35	23	873	4.7	8.2	4.7	0.6	12.3
45	25	1094	3.6	7.0	8.2	1.2	13.8
55	17	479	2.0	5.7	5.0	0.5	27.2
65	13	627	4.8	6.5	3.5	0.4	17.8
75	5	211	0.7	4.8	1.6	0.1	4.6
85	2	39	0.5	4.3	2.0	0.2	5.5
95	1	20	0	1.6	0.4	0	5.2
Average for all trees	52	8918	7.8	7.9	4.5	1.5	11.6

TABLE XXXI
COMPARISON OF AVERAGES OF VARIOUS HEIGHTS
WITH AVERAGE FOR ALL TREES IN GROUP

Trees 19-24 inches d.b.h.

Height	Trees sampled	Bark surface	Average per square foot: Brood	Attacks	Parasites	Predators	Rubber work
ft.	no.	sq.ft.	no.	no.	no.	no.	sq.in.
5	34	1828	15.9	10.3	2.6	5.1	6.6
15	34	2558	10.6	9.4	3.5	3.3	15.9
25	14	629	15.2	7.8	8.9	6.5	17.0
35	32	2022	7.7	9.0	4.5	1.0	14.8
45	13	583	8.3	6.9	4.7	1.8	35.8
55	14	626	3.9	7.7	4.5	0.8	26.2
65	13	797	4.3	9.5	3.5	1.0	11.5
75	7	343	0.9	7.1	7.5	1.3	16.6
85	4	101	0.7	5.0	2.2	0.6	59.5
95	1	28	0	1.5	0	0	0
105	1	24	0	3.0	10.5	1.0	18.5
Average for all trees	34	9539	8.3	9.4	4.2	2.7	17.3

TABLE XXXII
COMPARISON OF AVERAGE AT VARIOUS HEIGHTS
WITH AVERAGE FOR ALL TREES IN GROUP

Trees over 25 inches d.b.h.

Height	Trees sampled	Bark surface	Average per square foot				
			Brood	Attacks	Parasites	Predators	Rabbor work
ft.	no.	sq.ft.	no.	no.	no.	no.	sq.in.
5	8	559	8.2	11.8	0.9	6.9	13.3
15	8	791	6.1	8.5	2.5	6.4	7.9
25	2	121	7.2	8.3	2.1	10.7	3.8
35	6	500	9.8	9.6	1.7	3.4	8.7
45	4	322	5.8	8.9	0.8	1.9	10.2
55	3	145	14.6	12.1	4.9	2.8	3.2
65	4	420	6.6	9.9	1.2	1.2	6.4
75	3	314	1.7	7.2	1.0	1.9	76.1
85	1	47	3.0	6.0	1.0	0	6.5
Average for all trees	8	3219	8.5	9.4	2.0	5.6	15.8

The preceding four tables are summarized in table XXXIII to show at what height the maximum and average numbers of the various agents occur.

TABLE XXXIII
HEIGHT AT WHICH MAXIMUM AND AVERAGE
ABUNDANCE OCCURS

Diameter	Brood		Attacks		Parasites		Predators		Robber work	
	Max.	Av.	Max.	Av.	Max.	Av.	Max.	Av.	Max.	Av.
in.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
6-12	5	45	5	15-25	45	*	5	*	55	5
13-18	5	25	5	15-35	45	15-35	5	25	55	35
19-24	5-25	45	5	15 & 65	105	35-55	25	15	85	25
Over 25	55	5	5-55	35	55	25	25	*	75	*

* No point where average occurred.

Table XXXIII shows quite clearly that it would not be feasible to select a point on the tree where the average of all agents occurs. Even if it were possible to select one point for each agent, it would result in making several examinations along the bole, which would not improve the present method to any great extent because the same number of samples would be taken and it would be necessary to count all agents in each sample for the purpose of comparisons.

It is interesting to note in the preceding tables the effect of height upon the various insects. The mountain pine beetle apparently prefers and develops maximum broods in the thicker bark at the base of the tree. Predators are most abundant where maximum mountain pine beetle broods are produced, while parasites are found most abundant at that point where most abundant D. monticolae broods are produced under bark which is sufficiently thin for oviposition by Coeloides. Robbers do maximum work in the warmer upper portions of the tree, where mountain pine beetle attacks are fewer and there is more available

unused bark. There is a tendency for maximum mountain pine beetle broods to be produced higher up the tree as the trees increase in size.

One point upon which information was desired is shown in table XXXIV. This gives a comparison of conditions at the five-foot sample, with the average abundance of various factors in the entire tree. In this table the comparison is shown as a percentage which is positive or negative depending on whether the abundance at the base of the tree was greater or less than the average for the entire tree.

TABLE XXXIV
COMPARISON OF FIVE-FOOT SAMPLES WITH AVERAGE FOR THE TREE

Diameter group	Percent higher or lower than average for group				
	Brood	Attacks	Parasites	Predators	Robber work
in.					
6-12	+50.9	+25.0	+19.3	+90.0	+6.2
13-18	+78.2	+25.3	-15.5	+66.6	-43.7
19-24	+91.5	+ 9.5	-38.0	+88.8	-61.8
Over 25	- 3.5	+25.5	-55.0	+23.2	-15.8

Table XXXIV shows that there is considerable variation between conditions at the base of the tree and the average for the entire tree. Also, this difference varies depending on the diameter of the tree. In general, mountain pine beetle brood is more abundant at the base of the tree than the average. The abundance compared with the average increases from the smaller trees to the larger trees except that trees over 25 inches d.b.h. produced a brood at the base very close to the tree average. The number of attacks at the five-foot sample was

constantly 25 percent higher than the average except in the 19-24 inch diameter class. Parasites varied from more than 50 percent below average in the larger trees to 19 percent above average in the smaller ones. This is to be expected because as the smaller-diameter trees are reached the bark decreases in thickness at the base and parasites are more abundant. Predators, on the other hand, are constantly higher than average in the basal sample, although this percentage varies considerably. As would be expected, work by robbers is generally lower than average at the base of the smallest-diameter class. In general, if all diameters were equally represented, I believe the error would be small if one were to consider mountain pine beetle brood as 70 percent higher than average in the basal sample, attacks 25 percent higher, parasites 45 percent lower, predators 50 percent higher, and robber work 40 percent lower. In other words, after making a series of five-foot examinations one would reduce D. monticolae abundance and attacks by 70 percent and 25 percent respectively, increase parasite abundance and robber work by 45 and 40 percent respectively, and decrease the number of predators 50 percent.

Realizing that the total number of insects produced is dependent upon the amount of infested bark, which in turn depends largely upon the height to which a tree is infested, the following correlations have been made to determine the length infested under various conditions of height, diameter, and bark thickness. Table XXXV shows the effect of tree diameter upon the infested length.

TABLE XXXV
EFFECT OF D.B.H. UPON THE LENGTH OF INFESTED BOLE

D.b.h. in inches	6-9	10-13	14-17	18-21	22-25	26-29	30-31	40-41
Number of trees	19	48	64	44	14	8	1	1
Minimum length	19	10	10	20	19	54		
Maximum length	60	70	100	110	96	106		
Average length	27	40	47	61	63	72	83	155

Although there is an increase in the average infested length with each increase in diameter, the range within each diameter class is much too great to be of practical service. Hence, table XXXVI has been prepared to show the effect of tree height on the infested length.

TABLE XXXVI
EFFECT OF TREE HEIGHT UPON THE LENGTH
OF INFESTED BOLE

Height in feet	31-50	51-70	71-90	91-110	111-130	131-150	151-170	171-190
Number of trees	3	7	19	32	48	66	17	5
Minimum length	15	15	15	10	10	10	19	54
Maximum length	23	60	61	90	90	110	106	155
Average length	19	33	34	42	45	59	62	86

Although there is again a good correlation between tree height and the average infested length, the range within each height class is too great to make any application to individual trees. In an effort to ascertain the factor or factors which limit the infested length,

table XXXVII has been prepared to show the diameter and bark thickness at the height of infestation.

TABLE XXXVII
DIAMETER AND BARK THICKNESS AT THE HEIGHT OF INFESTATION

	Trees sampled	Range	Average	Maximum possible range
	no.	in.	in.	in.
Diameter	197	5.0 -21.0	11.5	5.0 -40.9
Bark thickness	197	0.15- 0.4	0.24	0.15- 1.2

Table XXXVII shows that diameter at the height of infestation averaged 11.5 inches, but that the range in diameter at this height was from 5 to 21 inches. With this wide range it is obvious that diameter at the height of infestation can not be used as a criterion in determining the infested length. Bark thickness, however, varies only within a limited range, which indicates that this is the factor which influences the highest point at which a tree is attacked. It has been pointed out that bark thickness varies greatly even within diameter or height classes, which explains why the variations occur in infested length in tables XXXV and XXXVI.

Table XXXVIII shows a correlation between infested length and bark thickness, and to eliminate the wide range when one factor is used alone height of the tree has been included.

TABLE XXXVIII
EFFECT OF BARK THICKNESS AND HEIGHT ON
LENGTH OF INFESTED BOLE

Tree height ft.	Bark thickness 0.9+ Range in inf. length	Av.	.7-.8 Range in inf. length	Av.	.5-.6 Range in inf. length	Av.	.3-.4 Range in inf. length	Av.	.1-.2 Range in inf. length	Av.
151-190	60-155	101	70-100	83	53-90	60	50-106	67	30-50	36
111-150	40-80	66	30-100	72	30-90	65	10-94	48	10-65	35
71-110	60-60	60	50-70	60	40-90	61	10-70	38	13-50	29
31-70					20-20	20	55-60	57	10-31	19
Average		80		78		62		48		31

Table XXXVIII shows that although there are some irregularities in the average infested length based on tree height and bark thickness, the range within each height and bark class is not nearly as great as when compared with height or diameter alone. It may be stated, therefore, that the mountain pine beetle is limited in its attack by bark thickness, which thus limits the height to which a tree is attacked. Bark thickness is dependent but slightly on the diameter of the tree, but height of the tree influences the taper of bark thickness.

SUMMARIZATION OF EFFECT OF ALL FACTORS ON BENEFICIAL INSECTS

In previous discussions most consideration has been given to the effect of various factors on the abundance of the mountain pine beetle. In this section a brief summary will be given to show the effect of

these various factors on the abundance of parasites and predators.

1 - Parasites and predators are most abundant in those trees which provide suitable host material at the time when these beneficial insects are ready for oviposition. Hence, those trees attacked early in the season provide mature or nearly mature mountain pine beetle larvae during July, and as a result approximately 50 percent of all parasites and predators is found in the early attacked tree.

2 - It has been shown that in general parasites and predators are most abundant where mountain pine beetle broods are most numerous. Thus the true value of these beneficial agents is masked when general averages are considered, because abundant brood in one tree will discredit 100 percent parasitization in another. In addition, parasites, such as Coeloides, are limited by bark thickness so that, if deep cracks are not present between bark ridges in thick-barked trees, this parasite can not oviposit.

3 - On the basis of site moisture, parasites and predators are most abundant on wet sites where monticolae broods are most numerous.

4 - Owing to the limited oviposition ability of Coeloides, parasites are most abundant in thinner bark such as is found on small trees and higher up the bole on larger ones. Conversely, predators and parasites which go beneath the bark to oviposit are most numerous under thick bark, hence in large trees and at the bases of all trees.

IMPORTANCE OF SLASH, CULL LOGS, AND WEAKENED TREES

Several different types of host material have been recognized on the Coeur d'Alene infestation, and it has been necessary to evaluate each type in relation to the infestation. The amount of mountain pine beetle brood produced per square foot in slash or weakened trees as compared with standing trees has never been clearly determined, although by actual observation some surprisingly accurate figures have been obtained regarding them. In the following discussions four types of host material have been recognized, namely, road slash and cull logs, logging slash and cull logs, windfalls and physically injured trees, and standing trees weakened by disease. Each of these will be considered separately.

Road Slash

In the areas examined by the infestation study all white pine trees cut in the process of road construction are cut into logs and sold. This left only tops and cull logs along most new roads. Table XXXIX shows conditions in both 1935 and 1936 road slash. The 1935 material was attacked during 1935 and examined at the time of emergence. The 1936 material was attacked and examined during 1936 and would not emerge until the summer of 1937.

TABLE XXXIX
CONDITIONS IN ROAD SLASH

Year of attack	Bark surface	Average per square foot of bark: Brood	Attacks	Parasites	Predators	Secondary work	Cerambycid work
		no.	no.	no.	no.	sq.in.	sq.in.
1935	2567	0.7	0.6	0.6	3.2	79.0	0.6
1936	2110	56.1	1.5	0.7	1.2	12.3	3.7

It is apparent that there was a negligible amount of emergence from the 1935 material and that most of the available bark space was used by Ips vancouveri and Pityogenes fossifrons. The mountain pine beetle brood per square foot appears high in the 1936 material owing to the fact that these broods were in an early stage of development, and considerable additional mortality will therefore occur. Road slash is not always attacked by the mountain pine beetle, as shown by examination of material along one road. Out of 117 pieces examined only 50 had been infested.

Logging Slash

The logging slash examined in this study comprised tops, cull logs, and stumps which were found on an experimental clear-cutting area. As very little shade remains following logging in the white pine type, it was felt that this area did not differ on this point from other logged areas. In this particular case the slash was scattered instead of being burned so that there would be more material than is ordinarily left after logging. Table XL gives the results of these examinations.

TABLE XL
CONDITIONS IN LOGGING SLASH

Bark surface	Average per square foot of bark					
	Brood	Attacks	Parasites	Predators	Secondary work	Cerambycid work
1210	0.1	.08	.09	.04	1.4	.05

The material shown in table XL was attacked during 1935 and examined at the time of emergence in 1936. It is quite apparent that conditions were decidedly unfavorable for the development of any insects.

Windfalls and Physically Injured Trees

The first two classes of host material represent that type which is subject to rapid drying owing to the fact that it has been severed from the roots. Windfalls and physically injured trees, however, maintain a full or partial root system for some time and thus provide some moisture to the developing broods. In this class are to be found windfalls, broken-topped and fire-scorched trees. During the course of the examinations in 1936, however, no fire-scorched material was available, so that table XLI represents only windfalls and broken-topped trees.

TABLE XLI
COMPARISON OF WINDFALLS AND BROKEN-TOPPED TREES WITH STANDING TREES

Type of material	Average per square foot						
	Brood	Attacks	Parasites	Predators	Secondary work	Cerambycid work	Woodpecker work
	no.	no.	no.	no.	sq.in.	sq.in.	sq.in.
Weakened trees	26.2	3.2	6.1	5.9	7.5	2.9	18.7
Standing trees	23.8	8.5	3.7	1.6	4.5	2.0	3.8

Table XLI bears out the belief that broods in windfalls are as abundant as those in standing trees even though there are 2½ times as many attacks in the standing trees as in the windfalls, and parasites, predators, and robbers are decidedly more abundant in the windfalls. It is obvious therefore that this type of host material is an important factor in infestations of the mountain pine beetle. With few attacks, this insect can produce more abundant progeny in windfalls than twice the number of attacks in standing trees.

Trees Weakened by Disease

This class comprises for the most part those trees which have been seriously damaged by the fungus Armillaria mellea. Unfortunately, owing to the type of damage which is the habit of this fungus, it is sometimes impossible to ascertain the intensity of the injury without exposing the entire root system. Even then it is difficult to make a comparative evaluation of the injury. Under these circumstances it is difficult to say whether these trees fall in the class with slash and cull logs, the class with windfalls and physically injured trees, or whether they represent a third class. Whatever the class, there is undoubtedly a wide variety of conditions represented by these trees, because they vary from those in which one side has been killed by the disease to those in which the presence of the fungus can be found only after digging around the lateral roots. One thing is certain, however, that they do represent a low-resistance class, but of what value has not as yet been determined.

BROOD POTENTIAL AND MORTALITY

If it is found possible to determine the status of an infestation by brood examinations, it will be necessary to know what normal mortality can be expected according to the developmental stage in which the broods are when examined. Accordingly, a portion of the study has been devoted to this subject, and although the data represent only one season's study, it was thought desirable to include them in this report.

Parent Adult Emergence

The fact that parent adult beetles emerge after having made an attack, and make a second attack in another tree, has definitely been established as a habit of the mountain pine beetle. Parent adult emergence then becomes an important factor in considering brood potential, and the question arises as to whether all females make two attacks. Table XLII gives some indication of this by comparing the average number of parent emergence holes with the average number of attacks.

TABLE XLII
COMPARISON OF PARENT EMERGENCE WITH ATTACKS FOR ATTACK PERIODS

	Attack period		
	Early	Midseason	Late
Parent emergence per square foot	6.25	5.52	3.65
Attacks per square foot	6.77	9.38	8.75

Table XLII shows that the number of parent emergence holes is almost equal to the number of attacks in the early trees, slightly more than half the number of attacks in the midseason trees, and less than half in the late trees. This is explained by the fact that the attacks in the early trees are made mainly by overwintering new adults, so that when these emerge the number of emergence holes is practically equal to the number of attacks. In the midseason trees the attacks are made in about equal numbers by new adults from overwintering trees and parent adults from the early attacks. Hence, as the new adults are the only

ones to emerge again, the parent emergence holes are about half the number of attacks. The late attacks are made principally by emerging parents from the midseason attacks and thus there are but few parent emergence holes compared with the number of attacks.

Many theories have been advanced concerning the cause of parent adult emergence. It has been thought that overcrowding may cause a higher percentage of the parents to emerge because of the fact that there was not sufficient room to complete galleries. Table XLIII shows the abundance of parent emergence according to the number of attacks.

TABLE XLIII
ABUNDANCE OF PARENT EMERGENCE BASED ON ATTACKS

	Attacks per square foot								
	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15 & 18	28 & 36
Parent emergence holes per square foot	2.1	3.4	5.1	6.2	7.0	7.1	6.7	7.5	5.6

Table XLIII shows that there is approximately one parent emergence hole per attack up to seven attacks per square foot, but beyond this point the number of emergence holes is fairly constant regardless of the number of attacks. This indicates that the density of attack has but little influence upon the number of emerging parent beetles.

Another theory advances the thought that under the influence of higher temperatures parent beetles complete one gallery rapidly and, finding bark conditions unfavorable for further egg laying, leave the tree for fresher material. Table XLIV shows the abundance of parent emergence holes on the four sides of the tree based on exposure, and table XLV shows the abundance of parent emergence holes according to the height along the bole.

TABLE XLIV
ABUNDANCE OF PARENT EMERGENCE HOLES ACCORDING TO EXPOSURE

	Exposure			
	North	East	South	West
Attacks per square foot	8.3	8.4	8.6	8.3
Parent emergence per square foot	5.5	5.6	6.1	5.6

TABLE XLV
ABUNDANCE OF PARENT EMERGENCE HOLES
ACCORDING TO HEIGHT ALONG BOLE

	6-12 inch class		13-18		19-24		over 25	
Height	Attacks	Parent e.h.	Attacks	Parent e.h.	Attacks	Parent e.h.	Attacks	Parent e.h.
ft.								
5	8.5	4.4	9.9	5.9	10.3	7.5	11.8	6.6
15	6.9	4.7	8.2	6.4	9.4	6.6	8.5	7.3
25	6.7	5.0	8.3	5.4	7.8	7.6	8.3	9.3
35	4.6	4.3	8.2	4.5	9.0	7.0	9.6	8.4
45	4.8	4.0	7.0	4.8	6.9	4.4	8.9	4.9
55	1.0	1.7	5.7	2.6	7.7	4.9	12.1	7.8
65	2.6	2.9	6.5	5.0	9.5	5.1	9.9	4.9
75			4.8	1.1	7.1	5.2	7.2	2.8
85			4.3	4.5	5.0	3.2	6.0	4.0
95			1.6	2.8	1.5	3.5		
105					3.0	1.5		

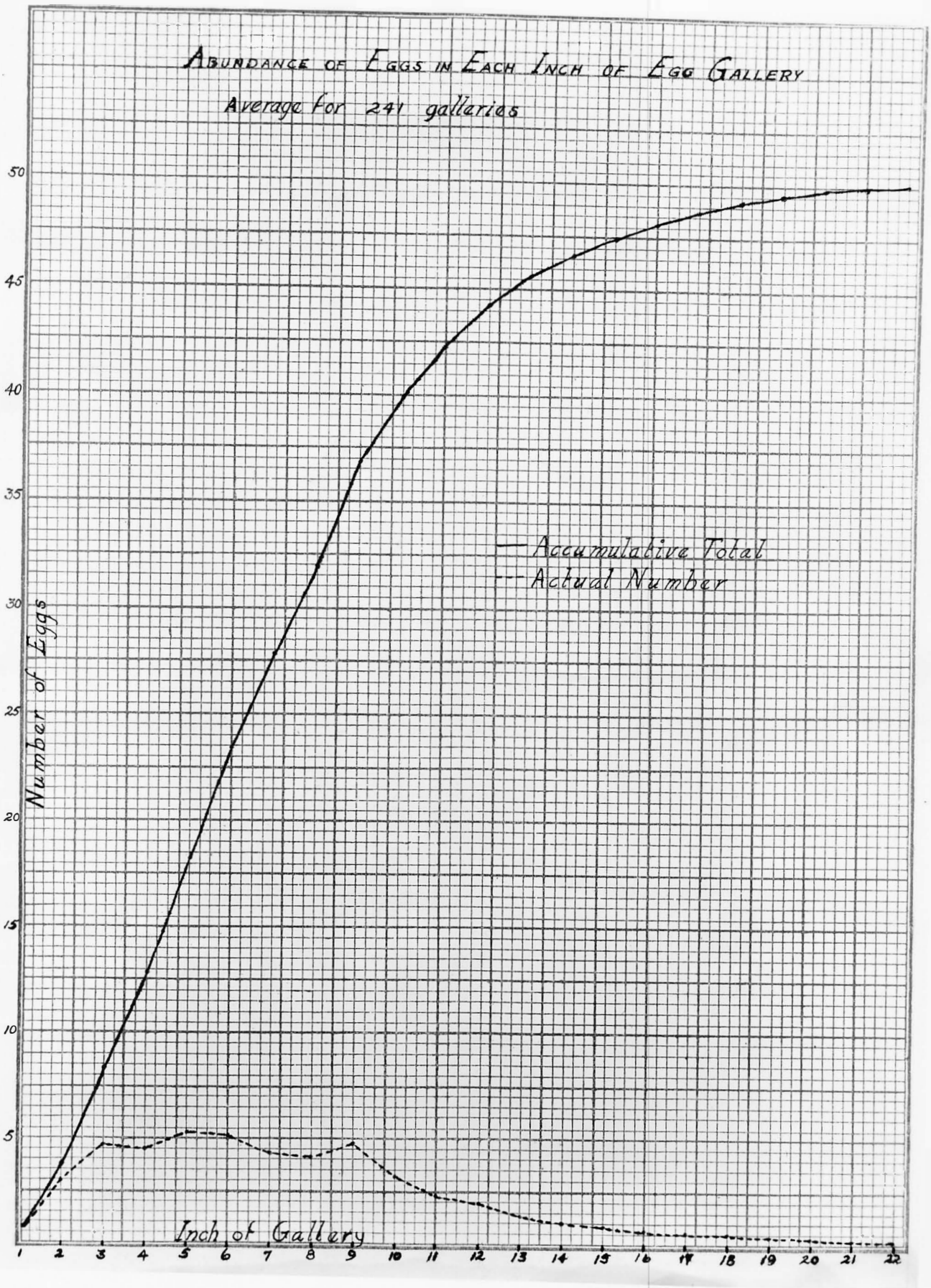
Table XLIV shows a slight tendency for parent emergence holes to be more abundant on the warmer south and west exposures. However, the difference is so slight as to be almost negligible. Table XLV shows

a very definite tendency for parent emergence holes to be more nearly equal to the number of attacks in the warmer upper portions of the bole. There are some points noticeable in the larger trees which do not conform to this general tendency. These may be explained by the fact that certain portions of the bole are shaded and thus are decidedly cooler than other portions exposed directly to the sun.

From available data it would appear that parent emergence is a normal habit of the mountain pine beetle which is influenced but little by environmental conditions. One may conclude therefore that where parent emergence holes are abundant compared with the number of attacks, most of the attacks were made by new adult beetles making their first attacks, and that where there are few parent emergence holes most of the attacks were made by parent beetles making their second attacks.

Brood Potential

In compiling the data relative to the number of eggs laid according to height along the bole, attack periods, exposure, etc., it was found that the number of eggs laid per gallery or per inch of gallery remained surprisingly constant, so that the average of all samples will apply to all conditions. Figure 2 shows the actual number of eggs laid per inch of gallery, as well as a cumulative total curve of all eggs laid.


Abundance of Eggs in Each Inch of Egg Gallery
Average for 241 galleries
Accumulative Total
Actual Number
Number of Eggs
Inch of Gallery
50
45
40
35
30
25
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

These curves show quite clearly that most of the eggs are laid between the second and eleventh inch of egg gallery, and that beyond the twelfth inch very few eggs are laid. Thus, an egg gallery from 10 to 12 inches long represents the optimum because it is the maximum in efficiency.

Mortality

With the small amount of data available it is impossible to formulate normal mortality figures which will hold throughout an entire infestation cycle. However, this section will show the mortality which occurred in the 1936 attacks up to the time of the examination.

Considering the number of eggs laid per square foot and the abundance of broods at the time of examination, a 40 percent mortality had already occurred to the 1936 broods. This is believed to be somewhat lower than normal mortality at this stage of development, because the total mortality from egg to emergence is considered to be approximately 90 percent, most of which occurs in the egg stage. However, a number of these trees will be examined during the 1937 season in order to determine the final figure.

PRACTICAL APPLICATION OF THE STUDY

Although only one season has been devoted to a detailed study of mountain pine beetle infestations in western white pine, it is already apparent that additional study will yield information which will have valuable practical application. For example, it is imperative that the status of an infestation be determined by the condition of various biological factors beneath the bark in addition to the usual count of the number of infested trees, because there may be a decided reduction in broods even though the number of infested trees remains constant. Indications are that further study such as that discussed in this report will eventually yield this desired infestation index.

Another valuable discovery is the apparently small number of beetles which are produced from trees growing on dry sites. These scattered trees growing at higher elevations have always been a source of trouble and expense on the various control projects. They have necessitated spotting and treating on high, brush-covered ridges where working conditions are difficult and infested trees are widely scattered. If it is found that these trees produce as many or more beneficial insects as mountain pine beetles, or if they produce fewer beetles than the number which attack, they need not be treated and the cost of control will be considerably reduced. In conjunction with the lack of broods in trees on dry sites, the abundant broods in trees on wet sites indicate where control will be most effective.

The present plan to revise mountain pine beetle control work so that it will be on a biologically sound basis necessitates detailed information concerning all beneficial insects. Hence, the infestation study provides data of the desired character. For example, the present indication is that there are more parasites than mountain pine beetles in trees under 10 inches d.b.h. which are growing on wet sites and which have been attacked during the early attack period. In fact, the present data show that all trees under 10 inches d.b.h. do not contain sufficient broods to warrant their treatment.

The lack of positive information has always made any consideration of slash and cull logs difficult. It is now apparent that a general policy regarding this type of host material can not be made and that each situation should be considered separately.

The infestation study also indicates that windthrown timber is of even more importance than formerly considered. Present data indicate that with less than half the number of attacks the mountain pine beetle can produce broods as great or greater in windfalls than in standing trees.

These are the main advantages which the first season's work indicates may be derived from the infestation study. However, with the large volume of data which is being secured from this annual study, it is possible that other important features may be forthcoming.

SUMMARY

1 - The mountain pine beetle infestation study in western white pine was begun on June 11, 1936, and has for its objective to study mountain pine beetle infestations in western white pine in order to obtain a better understanding of the factors that govern the behavior of these infestations.

2 - In comparing the infestation during 1935 and 1936 on the Coeur d'Alene National Forest, it appears that the 1936 trees were more lightly attacked, the broods were less heavily parasitized, and that there will be a more abundant emergence of D. monticolae in 1937 than there was in 1936.

3 - In general, the data indicate that there is no marked difference in the number of mountain pine beetles produced from trees in the different attack periods.

4 - The averages for all trees in all attack periods show that the mountain pine beetle is more abundant on the north and east sides of the tree, while attacks and those agencies which destroy the mountain pine beetle tend to be approximately equal regardless of exposure. However, when the averages for different attack periods are considered, it appears that the mountain pine beetle and its parasites and predators are most abundant on the south and west sides in the early and late-attacked trees, probably because of the lower temperatures which prevail at these times. On the other hand, robber work is most abundant on the warmer exposures at all times.

5 - Although the number of attacks per square foot is approximately equal on all sites and parasitization is more abundant on wet sites, there is a greater brood survival on wet sites and a greater amount of infested bark per tree, thus making a much greater total brood per tree than on dry sites.

6 - In determining the potentiality of any given infestation the actual increase or decrease in infested trees must be kept separate from the anticipated fluctuation indicated by brood examinations, because of the variation in size of trees, type of host material and density of attack from year to year. The true index is indicated by the number of female beetles produced per attack, and in order to make the index workable during any season of the year a constant must be applied for expected mortality and another for parent adult emergence. The mortality constant must be determined on the basis of beneficial insects and corrected for each stage in the insect's development.

7 - Bark thickness is an important factor in mountain pine beetle infestations in western white pine. From available data it appears that the mountain pine beetle prefers thick bark as indicated by abundance of attacks and is limited in its attack to bark over .2 of an inch in thickness. Parasites such as Coeloides dendroctoni, which oviposit through the bark, are limited to bark not thicker than the length of their ovipositer except where bark cracks permit them to oviposit in thicker bark. Conversely, other parasites and predators are more abundant in thicker bark. Because of the more abundant beneficial insects at the two extremes of bark thickness, mountain pine beetle

broods are most numerous where there is the lowest concentration of parasites and predators.

8 - Bark thickness is apparently the factor which governs the height to which a tree is successfully attacked.

9 - The data indicate that there apparently is an optimum number of attacks per square foot of bark which produces maximum broods. Where the attacks are of such numbers as to produce the maximum number of eggs with a minimum amount of egg gallery construction, the maximum number of individuals will reach maturity.

10 - On the basis of data from the trees attacked in 1935 it appears that in general, if all diameters were equally represented, the average for the infestation could be secured by taking only samples at the 5-foot height. The data secured from the samples should be revised to obtain the average by reducing the abundance of D. monticolae and its attacks by 70 percent and 25 percent respectively, increasing parasite abundance and robber work by 45 and 40 percent respectively, and decreasing the number of predators 50 percent.

11 - In general, parasites are most abundant in the smaller trees and upper portions of larger trees which are attacked early in the season and which are growing on wet sites. Predators are most abundant in bases of large trees which are attacked early in the season and which are growing on wet sites.

12 - Road slash and logging slash are apparently of little importance in building up infestations of the mountain pine beetle. Cull logs, particularly logs along new roads, may sometimes produce abundant broods of the mountain pine beetle.

13 - Windfalls and physically injured trees are more lightly attacked by the mountain pine beetle, but produce broods equal in numbers if not greater than those in standing trees.

14 - Parent adult emergence is a normal habit of the mountain pine beetle which is influenced but little by environmental conditions such as density of attack or ranges in normal developmental temperatures.

15 - The number of eggs laid per inch of egg gallery remains surprisingly constant regardless of height along the bole, attack periods, etc. Most of the eggs are laid between the second and eleventh inch of egg gallery, while beyond the twelfth inch very few eggs are laid regardless of the gallery length. Thus an egg gallery from 10 to 12 inches long represents the maximum in efficiency.

16 - From the time of egg deposition up to the time of examination the broods in the trees attacked during 1936 suffered an average mortality of 40 percent. These trees have yet to overwinter.